TITLE OF THE INVENTION

VACUUM PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a vacuum pump equipped with a main pump and a booster pump.

A vacuum pump is used in a semiconductor fabrication process and discharges a reaction product from a semiconductor process system. As the temperature in the booster pump of the vacuum pump becomes lower than the temperature in the main pump, a reaction product is solidified and deposited in the booster pump. Deposition of a reaction product in a gas passage leads to a reduction in the performance of the vacuum pump.

To overcome the problem, it is desirable to raise the temperature in the booster pump. Japanese Laid-Open Patent Publication No. 5-113180, for example, discloses a technique that permits heat in the housing of a main pump to be transmitted to the housing of a booster pump via a supporting member. This increases the temperature in the booster pump.

Japanese Laid-Open Patent Publication No. 8-296557 discloses a vacuum pump equipped with a multi-stage pump mechanism, which performs gas discharging in multiple stages. The temperature of that portion of the housing of the vacuum pump which surrounds the last stage of the pump mechanism or the portion that becomes the hottest becomes higher than the temperatures of the other portions.

However, the invention disclosed in Japanese Laid-Open

Patent Publication No. 5-113180 employs the aforementioned structure for the purpose of making the entire vacuum pump compact, the structure that is suitable for effectively raising the temperature in the main pump equipped with a multi-stage pump mechanism.

While, how to efficiently transmit the heat generated by the pump mechanism to the booster pump is important in effectively raising the temperature in the booster pump, the prior art describes nothing about this important point.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a vacuum pump capable of efficiently transmitting the heat in the main pump to the booster pump.

To attain the above object, the present invention provides a vacuum pump. The vacuum pump has a main pump, a booster pump and a coupling member. The main pump has a first housing and a first pump mechanism accommodated in the first housing. The first pump mechanism is a multi-stage type. The booster pump has a second housing and a second pump mechanism accommodated in the second housing. The booster pump and the main pump are coupled in series such that gas is sent from the booster pump to the main pump. The coupling member couples the first housing and the second housing to each other. The coupling member is directly coupled to a portion of the first housing that surrounds a last stage of the first pump mechanism such that transmission of heat to the portion is permitted.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by

way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a cross-sectional view of a vacuum pump according to one embodiment of the present invention;

Fig. 2 is a cross-sectional view along the line 2-2 in Fig. 1;

Fig. 3 is a partly cross-sectional view of a vacuum pump according to another embodiment of the embodiment; and

Fig. 4 is a partly cross-sectional view of a vacuum pump according to a further embodiment of the embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One embodiment of the invention will be described below with reference to Figs. 1 and 2.

(Outline of Vacuum Pump)

As shown in Figs. 1 and 2, a vacuum pump includes a main pump 11, which can be activated from the atmospheric pressure, and a booster pump 61. The vacuum pump is used in a semiconductor fabrication process and discharges a gaseous reaction product (e.g., ammonium chloride) from an unillustrated semiconductor process system. The booster pump 61 is located upstream (on the semiconductor process system side) of the position where the main pump 11 is located in the gas passage. The main pump 11 and the booster pump 61 are coupled in series. It is to be noted that the right-hand side in Fig. 1 is the front end of the vacuum pump and the left-hand side is the rear end of the

vacuum pump.

(Structure of Main Pump)

As shown in Figs. 1 and 2, the main pump 11 has a rotor housing member 12, a front housing member 13, and a rear housing member 14, which constitute a first housing H1. The front housing member 13 is connected to the front end of the rotor housing member 12, and the rear housing member 14 to the rear end of the rotor housing member 12. The first housing H1 accommodates a multi-stage root type first pump mechanism P1 to be discussed later.

The rotor housing member 12, the front housing member 13, and the rear housing member 14 are each made of an iron-based metal. Iron-based metals have smaller thermal expansion coefficient than, for example, aluminum-based metals. The iron-based metals can therefore reduce heat-oriented variation in the clearance of the individual sections to thereby ensure effective prevention of gas leakage or the like.

The first pump mechanism P1 will be elaborated below.

The rotor housing member 12 includes a cylinder block 15 and a plurality of first to fourth partition walls 16a, 16b, 16c, and 16d. The space between the front housing member 13 and the first partition wall 16a, the space between the first and second partition walls 16a and 16b, the space between the second and third partition walls 16b and 16c, the space between the third and fourth partition walls 16c and 16d, and the space between the fourth partition wall 16d and the rear housing member 14 are respectively equivalent to first to fifth pump chambers 51, 52, 53, 54, and 55. Formed in the four partition walls 16a, 16b, 16c, and 16d is a common passage 17, which connects the

adjoining pump chambers 51, 52, 53, 54, and 55.

A first rotary shaft 19 and a second rotary shaft 20 are rotatably supported on the front housing member 13 and the rear housing member 14, respectively. Both rotary shafts 19 and 20 are laid out in parallel to each other. The rotary shafts 19 and 20 are inserted into the first to fourth partition walls 16a to 16d. A plurality of (five in the embodiment) first rotors 23 are formed integrally on the first rotary shaft 19. Each first rotor 23 has the shape of a honewort leaf. Plural second rotors 28 (only one shown in Fig. 2) equal in quantity to the first rotors 23 are formed integrally on the second rotary shaft 20. Each second rotor 28 likewise has the shape of a honewort leaf. The thicknesses of the first and second rotors 23 and 28 in the axial directions of the first and second rotary shafts 19 and 20 become gradually smaller in order from the front housing member 13 toward the rear housing member 14.

The first and second rotors 23 and 28 are retained in engagement with each other in the first to fifth pump chambers 51 to 55 with slight clearances maintained. The volumes of the first to fifth pump chambers 51 to 55 become gradually smaller in order from the first pump chamber 51 toward the fifth pump chamber 55.

As shown in Fig. 1, a gear housing 38, which accommodates a gear unit 39 and a shaft coupling 40 is connected to the rear housing member 14. An electric motor M is mounted on the gear housing 38. The driving force of the electric motor M is transmitted to the first rotary shaft 19 via the shaft coupling 40 and is transmitted from the shaft coupling 40 to the second rotary shaft 20 (see Fig. 2) via the gear unit 39. The second rotary shaft 20 (second rotors 28) is turned in a direction different from the

turning direction of the first rotary shaft 19 (first rotors 23).

A gas suction port 21 is formed in the cylinder block 15 at the upper part of a portion (peripheral wall) 45 of the foremost stage of the first pump mechanism P1 (the portion that is constituted by the first pump chamber 51 and the first and second rotors 23 and 28 to be retained in the first pump chamber 51). The portion 45 surrounds the first pump chamber 51 in such a way that the suction port 21 communicates with the first pump chamber 51. The suction port 21 is connected with the exhaust side of the booster pump 61. A gas exhaust port 22 is formed in the cylinder block 15 at the lower part of a portion (peripheral wall) 46 of the last stage of the first pump mechanism P1 (the portion that is constituted by the fifth pump chamber 55 and the first and second rotors 23 and 28 to be retained in the fifth pump chamber 55). The portion 46 surrounds the fifth pump chamber 55 in such a way that the exhaust port 22 communicates with the fifth pump chamber 55.

The gas from the booster pump 61 that is led into the first pump chamber 51 through the suction port 21 is transferred to the adjoining second pump chamber 52 via the passage 17 in the first partition wall 16a as the first and second rotors 23 and 28 in the first pump chamber 51 rotate. The gas is transferred in a similar manner in the order from a larger-volume pump chamber to a smaller-volume pump chamber, i.e., in the order from the first pump chamber 51 toward the fifth pump chamber 55 through the second, third and fourth pump chambers 52, 53, and 54. The gas that has been transferred to the fifth pump chamber 55 is discharged toward an unillustrated exhaust-gas process system from the exhaust port 22.

(Structure of Booster Pump)

As shown in Figs. 1 and 2, a great structural difference between the main pump 11 and the booster pump 61 lies in that the main pump 11 is a multi-stage (five stages in the embodiment) root pump, which performs gas discharging in multiple stages, whereas the booster pump 61 is a single-stage root pump, which performs gas discharging in a single stage. With regard to the booster pump 61, therefore, only what differs from the main pump 11 will be described, and the description of those components of the booster pump 61 that are identical or correspond to the components of the main pump 11 will be omitted with the same reference symbols given to the corresponding components.

The booster pump 61 also has a rotor housing member 12, a front housing member 13, and a rear housing member 14. The rotor housing member 12, the front housing member 13, and the rear housing member 14 constitute a second housing H2, which accommodates a single-stage root type second pump mechanism P2. The rotor housing member 12 of the booster pump 61 does not have the first to fourth partition walls 16a to 16d of the main pump 11. The space in the rotor housing member 12 that is defined between the front housing member 13 and the rear housing member 14 is a sixth pump chamber 62, which is larger in volume than the first pump chamber 51 of the main pump 11. A first rotary shaft 119 and a second rotary shaft 120 of the booster pump 61 are respectively provided with a first rotor 63 and a second rotor 64 both having the shape of a cotyledon. The first and second rotors 63 and 64 are retained in engagement with each other in the sixth pump chamber 62 with a slight clearance kept therebetween.

A suction port 65 is formed in the upper portion of the cylinder block 15 of the booster pump 61 in such a way as to

communicate with the sixth pump chamber 62. The suction port 65 is connected with an exhaust-side pipe of the semiconductor process system. An exhaust port 66 is formed in the lower portion of the cylinder block 15 in such a way as to communicate with the sixth pump chamber 62. Therefore, the gas from the semiconductor process system, which is led into the sixth pump chamber 62 through the suction port 65, is discharged toward the main pump 11 from the exhaust port 66 as the first and second rotors 63 and 64 rotate.

(Support Structure for Booster Pump)

As shown in Figs. 1 and 2, a support portion 67 as a support member is formed integrally with, and protrudes on, the lower portion of the cylinder block 15 of the booster pump 61. A support and protrusion portion 68 is formed integrally on the lower portion of the rear housing member 14 of the booster pump 61. A rubber bush 47 is attached to the upper portion of the rear housing member 14 of the main pump 11.

The booster pump 61 is fixed to the top surface (flat surface) 15a of the cylinder block 15 of the main pump 11 by the support portion 67, and is securely mounted on the main pump 11 by the support and protrusion portion 68 placed on the rubber bush 47. That is, the support portion 67 of the booster pump 61 serves as a support stand for supporting the booster pump 61 on the main pump 11.

A communication passage 69, which connects the exhaust side (exhaust port 66) of the booster pump 61 to the suction side (suction port 21) of the main pump 11, is formed inside the support portion 67. Specifically, in the support portion 67, an exhaust flange 70 that is connected to the exhaust port 66 of the booster pump 61, a suction flange 71 that is connected to the suction port 21 of the main pump 11

and a communication portion 72 that connects both flanges 70 and 71 together are integrated with one another. The suction flange 71 is connected to the top surface, 45a, of the portion 45 of the cylinder block 15 that surrounds the first pump chamber 51 of the first pump mechanism P1. The shape of the communication portion 72 becomes narrower toward the suction flange 71 along the shape of the communication passage 69.

As the booster pump 61 is securely mounted on the main pump 11 via the support portion 67 in this way, the cylinder blocks 15 of the main pump 11 and the booster pump 61 are directly connected to each other by the support portion 67 such that transmission of heat to the cylinder block 15 of the booster pump 61 is permitted. Therefore, the heat in the main pump 11 is transmitted to the cylinder block 15 of the booster pump 61 from the cylinder block 15 of the main pump 11 via the support portion 67 of the booster pump 61, thereby raising the temperature inside the booster pump 61 (including the inside of the communication passage 69). Raising the temperature in the booster pump 61 prevents the solidification of a reaction product in the booster pump 61.

As mentioned above, the embodiment uses a multi-stage root pump as the main pump 11. Therefore, the temperature of the portion 46 of the cylinder block 15 of the main pump 11 that surrounds the last stage of the first pump mechanism P1 or the portion that becomes the hottest becomes higher than the temperatures of the other portions (for example, the portion 45 that surrounds the foremost stage). To efficiently increase the temperature in the booster pump 61 by using the heat generated in the main pump 11, therefore, it is necessary to transmit the heat at the high-temperature portion of the cylinder block 15 of the main pump 11 to the cylinder block 15 of the booster pump 61.

In this respect, the support portion 67 of the booster pump 61 is directly coupled to the (high-temperature) portion 46 of the cylinder block 15 of the main pump 11 such that transmission of heat to the cylinder block 15 of the booster pump 61 is permitted. Specifically, a flat heat-extracting portion 73 is formed on the suction flange 71 of the support portion 67 in such a way as to extend toward the rear housing member 14. The heat-extracting portion 73 is directly mounted on the top surface 15a of the cylinder block 15 of the main pump 11 in an area between the top surface 46a of the (high-temperature) portion 46 and the top surface 45a of the portion 45 to include the top surface 46a.

Therefore, the heat generated by the last stage of the first pump mechanism P1 is taken directly to the support portion 67 via the heat-extracting portion 73 from the high-temperature portion 46 of the cylinder block 15. This can effectively raise the temperature in the booster pump 61, thus reliably ensuring the prevention of the solidification of a reaction product in the booster pump 61.

The embodiment has the following advantages.

The heat generated by the last stage of the first pump mechanism P1 can efficiently be transmitted to the booster pump 61, thereby effectively raising the temperature in the booster pump 61. This makes it possible to more reliably prevent the solidification of a reaction product in the booster pump 61, thereby surely inhibiting a reduction in the performance of the vacuum pump that would otherwise be originated from the deposition of a reaction product in the gas passage.

The support portion 67 is formed integrally on the

cylinder block 15 of the booster pump 61. This ensures efficient thermal conduction between the support portion 67 and the cylinder block 15 of the booster pump 61, thus making it possible to raise the temperature in the booster pump 61 more effectively. Further, it is unnecessary to separately provide the support portion 67 for both pumps 11 and 61, thereby contributing to reducing the number of components of the vacuum pump.

The support portion 67 also serves as the support stand that supports the booster pump 61 on the main pump 11. This makes it unnecessary to provide an exclusive support stand for supporting the booster pump 61, thereby also contributing to reducing the number of components of the vacuum pump.

The communication passage 69, which connects the exhaust port 66 of the booster pump 61 to the suction port 21 of the main pump 11, is formed inside the support portion 67. This eliminates the need for an exclusive pipe for forming the communication passage 69, so that the number of required components of the vacuum pump can be reduced.

As the heat-extracting portion 73 is formed on the suction flange 71 of the support portion 67, the support portion 67 abuts on the top surface 15a of the cylinder block 15 of the main pump 11 in a wider area stretching from the top surface 45a of the portion 45 corresponding to the foremost stage of the first pump mechanism P1 to the top surface 46a of the portion 46 corresponding to the last stage of that. Accordingly, the booster pump 61 is stably supported on the main pump 11 by the support portion 67.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific

forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

As shown in Fig. 3, for example, the support portion 67 may be formed integrally on the cylinder block 15 of the main pump 11. As another embodiment, the support portions 67 may be formed separately on the cylinder block 15 of the main pump 11 and the cylinder block 15 of the booster pump 61 as shown in Fig. 4. Alternatively, the support portion 67 may be formed integrally on both the cylinder block 15 of the main pump 11 and the cylinder block 15 of the booster pump 61, though not illustrated.

A thermal conductive grease as a thermal-conductance improver may be intervened in the portion where the support portion 67 is connected to the cylinder block 15 of the main pump 11. This improves the adhesion of the support portion 67 to the cylinder block 15 of the main pump 11, thus improving the thermal conductance between those cylinder block 15 and support portion 67. As a result, the temperature in the booster pump 61 can be raised more effectively. A substitute thermal conductive material for the thermal conductive grease may be a copper paste, a resin sheet, or a rubber sheet.

The heat-extracting portion 73 may be separated from the support portion 67, and the separated heat-extracting portion 73 may be provided on the cylinder block 15 of the booster pump 61 separately from the support portion 67. In this case, the heat-extracting portion 73 only serves as a coupling member. This structure can allow the heat from the heat-extracting portion 73 to be transmitted directly to the cylinder block 15 of the booster pump 61, so that the temperature in the booster pump 61 can be raised more

efficiently.

The support portion 67, the support protrusion portion 68 and the bush 47 may be eliminated, and the booster pump 61 may be mounted directly on the main pump 11. In this case, the cylinder block 15 of the booster pump 61 that is connected directly to the cylinder block 15 of the main pump 11 serves as a coupling member. This structure causes the (high-temperature) portion 46 of the cylinder block 15 of the main pump 11 to directly abut on the cylinder block 15 of the booster pump 61, so that the heat generated by the last stage of the first pump mechanism P1 of the main pump 11 can be transmitted to the booster pump 61 more efficiently. This mode is advantageous in making the vacuum pump compact.

At least the cylinder block 15 (inclusive of the support portion 67 integral with the cylinder block 15) in the second housing H2 of the booster pump 61 may be formed of an aluminum-based metal, which has an excellent thermal conductance. This structure can allow the heat from the heat-extracting portion 73 to be efficiently transmitted to the cylinder block 15 of the booster pump 61, thus making it possible to raise the temperature in the booster pump 61 more efficiently.

The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.